# LOWER YAKIMA VALLEY GWMA PROPOSED AMBIENT GROUNDWATER MONITORING NETWORK

**June 8, 2016**

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# SIGNATURE

This report, and Pacific Groundwater Group's work contributing to this report, were reviewed by the undersigned and approved for release.

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# 1.0 INTRODUCTION

The Groundwater Advisory Committee (GWAC) for the Lower Yakima Valley Groundwater Management Area (GWMA) requested the design of a purpose-built groundwater monitoring system to establish a baseline of groundwater quality conditions near the water table in the GWMA. The water table is being targeted since little data from this zone exists, and because concentration changes associated with land use change will occur there first. The design considerations were:

- Target the water table or shallow aquifer
- Establish reasonable well density
- Consider the availability of alternative sampling locations
- Consider the general pattern of land use but avoid locations likely to be anomalous as a result of local man-made or natural conditions
  - Include a scale of prioritization indicating which of the specific wells should be given the highest priority for early installation

The network designed using those guidelines will be appropriate for tracking concentration changes at the water table over time. It may also allow mapping of the variation in concentration at the water table. The confidence associated with calculated averages and variation will be sensitive to the number of wells installed, which is not yet determined.

The following report presents the method used to generate a groundwater monitoring network composed of wells, and the results of that work – preliminary drill sites. A comparison of preliminary drill sites to general land use in the GWMA is presented, as well as a discussion on how a monitoring network at irrigation drains can be used to augment groundwater monitoring at wells. Interim work products were presented to the GWMA Data Committee in the form of two technical memoranda (PGG, 2016a; PGG, 2016b) which were discussed on April 13 and May 11, 2016. This final report includes information in the prior memos, and presents network installation cost estimates and timelines.

This work was performed, and this report prepared, in accordance with hydrogeologic practices generally accepted at this time in this area. The resulting report is for the exclusive use of the Lower Yakima Valley Groundwater Advisory Committee and Yakima County for specific application to the Lower Yakima Valley. This is in lieu of other warranties, express or implied.

# 2.0 GENERAL WELL LOCATION METHODOLOGY

To be responsive to the design considerations, a method was developed that distributed and ranked monitoring points using only the geographic shape of the GWMA. These points were subsequently adjusted to facilitate permanent access and avoid potentially anomalous areas, consistent with GWAC design considerations. The following subsections provide details on this method.

## 2.1 INITIAL RANDOM MONITORING POINT POOL

*Initial Random Monitoring Points* were generated using the Geographical Information System program ArcMap, which was used to first randomly distribute 1000 points across and within the GWMA (excluding the EPA monitored dairy-cluster area). The ArcMap Create Random Points (ESRI, 2016) tool used was to generate this distribution. These interior points created a pool from which *General Well Locations* were selected. General information on random sampling can be found in Gilbert (1987) and EPA (2009).

## 2.2 GENERAL WELL LOCATION SELECTION AND RANKING

Ranked General Well Locations were selected from the pool of Initial Random Monitoring Points. The resulting ranked set of General Well Locations was based on the following process:

- The first location selected is the point furthest from the GWMA boundary; this location approximates the centroid of the GWMA.
- The second General Well Location is the point that is farthest from the combination of the boundary and the first General Well Location. This is the middle of the largest unsampled area.
    - Each subsequent General Well Location is the point closest to the center of the largest un-sampled area. This evenly distributes general well locations throughout the GWMA and ranks them by the size of the un-sampled area.

Figure 1 presents the first 30 General Well Locations as selected and prioritized by the method presented above. Additional locations could be identified using this process in the future. Following the selection of ranked General Well Locations, Preliminary Drill Sites (discussed below) were selected by identifying nearby public land where potential anomalous groundwater nitrate concentrations were not expected.

## 2.3 PRELIMINARY DRILL SITE SELECTION

Preliminary Drill Sites are refined from the General Well Locations by evaluating surrounding land use. Public lands, canals, agricultural drains, dairies, parcels with septic systems, and known existing monitoring wells were mapped to help select preliminary drill sites. Additionally, road signage and roadside images were reviewed to identify relatively safe sites. The preliminary drill sites were not inspected by visitation. The following bullets describe how each factor was considered.

- Groundwater flow directions and irrigation features (canals, joint drains, lateral canals, and drainage ditches) were mapped to assess up-gradient and down-gradient locations for identifying Preliminary Drill Sites.
- Preliminary Drill Sites were moved from the center of the General Well Location to the nearest public land, subject to the additional criteria below. We recommend that final drill sites be selected near the Preliminary Drill Sites based on field inspection and utility clearances.

- Irrigation canals and joint drains (which have multiple drainage ditches flowing into them) can lose water to the ground and may influence groundwater quality in their vicinity. Preliminary Drill Sites were not located within approximately one-quarter mile from irrigation canals and joint drains.[1] Data from the Columbia Basin GWMA support using a setback from irrigation features (Columbia Basin GWMA, 2008).
- Lateral canals and drainage ditches are smaller features which also may lose water and locally affect groundwater quality. Preliminary Drill Sites were not located within approximately 200 feet from these features.
- Preliminary Drill Sites were not located within one-quarter mile downgradient from other known land uses that may result in anomalous groundwater nitrate concentrations. In application, only one site was moved on this basis: Preliminary Drill Site 7 was moved away from the Port of Sunnyside sprayfield. In addition, although Preliminary Drill Site 23 was not near a dairy or sprayfield, the closest public land with sufficient canal offset was within the EPA dairy-cluster area; therefore the drill site was moved further away to be outside of the cluster.
- Existing publically-owned water table monitoring wells were mapped based on information in the Ecology well log database to assess the availability of pre-existing wells. The accuracy of the monitoring well map coverage is likely imperfect. Use of existing wells is subject to field verification, water table completion, and agreement with the (public) well owner. In practice, no existing monitoring wells were mapped within ¼ mile of the General Well Locations,[2] and therefore existing wells are not proposed for monitoring in lieu of the purpose built wells proposed within this plan.
- Street-view imagery from Google Street View is available for much of the Lower Yakima Valley, and was reviewed for each Preliminary Drill Site (where available) to identify intersections with stop signs, locations with suitable road shoulders, and the presence of overhead lines or other utilities that could interfere with drilling. Mapped irrigation features were also reviewed to assess if they are subsurface pipes and therefore not expected to leak significantly.

# 3.0 PRELIMINARY DRILL SITES

Preliminary Drill Sites are shown in Figure 2, with more detailed maps of each site in Appendix A, Figures A1 to A30. Site descriptions are presented in Table 1, and include a general summary of the Preliminary Drill Site and the rationale used when moving away from the General Well Location to the Preliminary Drill Site.

Depth to water estimates were used to develop well drilling cost estimates. Depth to water estimates come from mapped regional water table elevations (Vaccaro and others, 2009), with linear interpolation applied to estimate elevations between mapped contours; depth to water was then calculated by subtracting this elevation from surficial elevations based on USGS 1:24,000 topographic maps. We have assumed that all wells will be screened over 20 vertical feet extending down from the water table at the time of drilling; however, these well depths are estimates, and actual depths are expected to differ. A

[1] PGG initially considered providing setbacks from canals only.

[2] Monitoring wells logs near General Well Locations 7 and 22 were reviewed based on their proximity to the Preliminary Drill Sites, but these monitoring wells were either decommissioned or mis-located.

comparison of water levels measured at 10 EPA monitoring wells in the dairy cluster to USGS estimates found half of the wells were within 15 feet of the USGS estimate, while the other half had estimates between 33 feet too high and 126 feet too low. Areas with the greatest discrepancies generally appear to be in higher elevation areas near the edge of the valley and in the vicinity of the Roza Canal. Therefore, in some instances (at sites 15 and 25), professional judgement was used in estimating depths to water based on observed EPA-well water levels.

## 3.1 PRELIMINARY DRILL SITE LOCATIONS IN RELATION TO SHALLOW BASALT

Shallow geology within the GWMA is primarily alluvial and semi-consolidated basin fill sediments; however, shallow basalt occurs in some areas, which could influence the optimal drilling method. Also, some basalt is of such low permeability that it will not yield sufficient water to a monitoring well.

To evaluate this issue, Preliminary Drill Site well depths were compared to estimated top of basalt elevations. Regional USGS data were used to approximate the top of basalt elevation and the water table elevation (Vaccaro and others, 2009). As discussed in Section 3.0, subsurface elevations based on the USGS regional characterization may differ from observed actual elevations. In areas where basalt elevations are expected near or above the water table, local well logs from Ecology's well log viewer were reviewed to evaluate basalt and groundwater depths. Areas identified where basalt will likely be encountered above the water table are:

- Preliminary Drill Site 14: it is very likely that basalt will be encountered before the water table at this location.
- Preliminary Drill Site 18: it is likely that basalt will be encountered before the water table at this location.
- Preliminary Drill Sites 9 and 24: it is possible that basalt may be above the water table at these locations, or that saturated sediments will be encountered but will not be 20 feet thick (which is the assumed screen length).
- Preliminary Drill Site 4: basalt may be observed at this location, but it is likely that 20 feet of saturated sediments are present.

Though there is uncertainty in what the constructed depths of the wells will be and the geologic materials that they will encounter, we assume that wells will not be moved in response to expected shallow geology - thus retaining a basin-wide water table monitoring network that is not limited to basin fill areas.

In instances where basalt is encountered during drilling, the following decision process is proposed:

- If basalt of any character is encountered but at least 15 ft of saturated sediments with high permeability (silty sand or coarser) are present, a well should be completed within the sediments only.

- If water-bearing basalt is encountered at the water table, the saturated basalt should be screened.
- If dense basalt with low permeability is encountered at the water table and will have insufficient yield to support a well, the borehole should be abandoned (decommissioned) and the next well in the ranked priority should be drilled.
- Detailed well construction and completion decisions will need to be made in the field in response to the field data. In general, saturated materials with low permeability (for basalt and sediments) will be avoided for screened sections because they compromise well performance and sample representativeness.

# 4.0 COMPARISON OF PRELIMINARY DRILL SITES TO GENERAL LAND USE

Figures 2 and 3 map preliminary drill sites relative to land use. Figure 2 shows that Preliminary Drill Sites 1 through 9 (the highest priority sites) are all in the lower (southeast) part of the GWMA, that nearly all the drill sites are located close to agricultural land uses, and that several are also near residential, cultural/recreation lands, and undeveloped land. Site 12 appears to be the only site surrounded by non-agricultural uses (it is in Grandview). Sites 1, 5, and 20 (all near Sunnyside) also have significant residential and commercial land uses nearby.

Whereas Figure 2 lumps all agricultural land uses, Figure 3 differentiates various irrigated agricultural land categories according to a method developed for the GWMA's Deep Soil Sampling work (PGG, 2014b), and presented in Table 2. The method defines categories of fields that have three parameters in common:

- NRCS nitrate leaching potential (primarily represents soil type)
- Crop rooting depth (represents crop types)
- Irrigation type (represents potential for over-irrigation)

Figure 3 maps only the ten largest categories according to acreage (they make up 96 percent of the total irrigated acreage)[3]. White areas on the map are a land use other than irrigated agriculture (see Figure 2). The categories mapped on Figure 3 are defined below in order of decreasing acreage.

# 5.0 GROUNDWATER MONITORING WITH DRAINS

Given the relatively high installation cost of purpose-built monitoring wells, supplemental groundwater monitoring using the existing irrigation drain[4] network (ie drainage ditches and wasteways) in the GWMA was considered. Given that drains have no addi-

[3] A category with "unknown" irrigation type was excluded.
[4] The drain network as referred to in this report includes the drainage ditches and wasteways conveying water from and between fields. Tile drains are not included in our term "drainage network" or "drains" since they are maintained on a field-scale by landowners and are not mapped basin-wide. All return-flow features interconnecting fields are henceforth referred to as "drains" in this report.

tional installation costs, pumps or passive samplers are not necessary for sampling, and they can be sampled in minutes (relative to approximately an hour for sampling a monitoring well with a pump), groundwater monitoring data from drains is much less expensive than data from wells.

While data produced from a drain monitoring network will differ from a monitoring well network (as further discussed below), both well and drain monitoring programs can be pursued in parallel.

## 5.1 CONCEPTUAL DRAIN MONITORING APPROACH

Nitrate concentrations in Yakima Valley drains vary in response to the irrigation season. Irrigation in the Yakima Valley typically occurs from April through October, with water from the Yakima River diverted through canals and ultimately applied to fields. During this period, unused irrigation water, irrigation runoff, and water intercepted by subsurface tile drains is conveyed to drains, and ultimately discharges to the Yakima River. Most of the water present in the drains during this period is water diverted from the Yakima River. Since nitrate and nitrogen concentrations in Yakima River water are low, nitrate concentrations in the drain line water are also relatively low during irrigation months.

During the non-irrigation season (roughly November through March), water diversion from the Yakima River ceases, and water present in the drains is predominantly groundwater that continues to enter those features. Multiple studies in the Yakima Valley (Ebbert and others, 2003; Zuroske, 2009) and from the irrigated part of the Central Columbia Plateau (Williamson and others, 1998) have found elevated nitrate concentrations in drains during the non-irrigation season due to the un-diluted discharge of higher concentration groundwater. Example data plots from existing reports showing this trend are presented in Figure 4. Figure 4a plots drain-water nitrate concentrations and streamflow, and shows that nitrate concentrations are high when flow is low. Figure 4b is a set of bar graphs plotting median monthly nitrate concentration and flow values for the Granger Drain and Sulphur Creek Wasteway; a comparison of the two bar graphs indicates that higher nitrate concentrations occur in non-irrigation months when groundwater discharge is not diluted.

Apart from differences in cost, groundwater data collected from drains will differ from data collected from wells in several ways, and in some cases may pose benefits or limitations relative to data collected from wells. These differences include:

- Groundwater collected from drains will be an aggregate of groundwater discharged to the drains over potentially large areas that may not be well known. The shallow aquifer capture area for a given drain may be affected by numerous spatially distributed land uses. Groundwater sampled from monitoring wells, on the other hand, is captured from a relatively small area of the shallow aquifer and will be effected by land use directly upgradient of the well.
- For groundwater to discharge to a drain, the water table must intersect the bottom of the drainage feature, groundwater must flow toward the drain, and there must be hydraulic continuity between the drain and aquifer. Therefore water-tight pipelines or areas with paved drainage ditches will receive limited groundwater discharge. In areas of the GWMA with higher elevations that are relatively far from the Yakima River, groundwa-

ter will not discharge to drains because the water table is lower in elevation than the drain bottom. Thus the entire GWMA cannot be monitored by sampling drains, and the available drain sampling stations cannot be randomly located.

- Upstream/downstream sampling and/or studies where multiple sampling locations are present along a discharge path can easily be performed using drains. These data could be used to evaluate nitrate contributions from different drain segments.
- Given that nitrate concentrations in drains are only representative of groundwater concentrations during non-irrigation months, drain data cannot be used to evaluate seasonality of groundwater nitrate concentrations. Monitoring well data are necessary to evaluate seasonal groundwater nitrate concentrations in the GWMA.

Because of these differences, we recommend maintaining and evaluating drain monitoring data separately from well data, and therefore have not altered proposed well monitoring locations based on the presence/absence of proposed drain monitoring locations discussed below.

## 5.2 PROPOSED DRAIN SAMPLE STATIONS

A total of 25 drain sampling stations are identified on Figure 5 and Table 3 based on the distribution of drains, the occurrence of shallow groundwater, and the presence of historical nitrate sampling data. Sampling stations, as discussed below, were not randomly selected and generally are proposed near the Yakima River at drain mouths or upstream at relatively large joint drain junctions. Digital drain coverages for the Sunnyside Valley and Roza[5] irrigation districts where reviewed; however, we were unable to review drain coverages in some of the smaller irrigation districts (Union Gap, Buena, Home, Grandview, and Zillah) present in the GWMA, and therefore additional sampling locations in some of these irrigation districts could be added based on local knowledge or if mapped coverages become available.

Data from Ecology's Environmental Information Management (EIM) database for the Lower Yakima Valley were downloaded to identify historical drain sampling locations. Where possible, proposed sampling locations were located adjacent to historical sampling sites with the intent of combining data sets. In total, 19 out of the 25 proposed sampling locations have historical data. Coordination with the Roza-Sunnyside Board of Joint Control (RSBOJC) and USGS is recommended to obtain any additional monitoring data (historical or current) that are not available in the EIM database.

As shown in Figure 5 and Table 3, most drains have one sample location proposed, though some larger drains with numerous tributaries (Granger Drain and Sulphur Creek Wasteway) have multiple sampling locations proposed. Both the Granger Drain and Sulphur Creek Wasteway have large drainage areas, and it is likely that nitrate concentration changes will be more detectable at the smaller scale/more localized drain monitoring stations.

[5] Roza Irrigation District wasteways were reviewed, while all other drains in the Roza District are managed by land owners and could not be reviewed at a valley-wide scale.

We recommend that each drain site initially be sampled to establish its seasonal signature of flow and nitrate concentration. That could be accomplished with a minimum of six samples collected bimonthly over a year. Subsequent sampling (targeting groundwater only) should occur only in winter at stations exhibiting a signature of surface water dilution during the irrigation season.

While winter flow is expected at all proposed sampling locations, it is possible that some may not have flow or may have access limitations. If this is the case, other nearby sampling locations should be considered. Coordination with other entities (RSBOJC, USGS, others) is also recommended since they currently may be monitoring some of the proposed drain sampling locations. Field verification and marking of sampling locations should be performed as part of a future scope of work.

# 6.0 ESTIMATED COSTS

Costs for well drilling, well sampling, and drain sampling are presented in the following subsections. Costs are planning-level estimates and will likely differ from actual costs depending on management decisions and market conditions.

In addition to drilling contractor costs, the GWMA will incur other costs related to drilling and sampling that are only briefly covered in the discussions to follow. Management decisions are required to select personnel for that work. The work includes technical oversight during drilling (geologic logging, in-field well design, documentation, well testing, and as-built reporting), and a professional survey of well head locations and elevations. Field services and data analysis cost estimates are included in Table 4 for reference, and are subject to the numerous assumptions listed at the bottom of Table 4.

Sampling supplies and lab costs are not included beyond the one year assumed for the initial effort summarized below.

## 6.1 WELL DRILLING COSTS

Estimated drilling costs for the installation of monitoring wells is dependent on drilling method and depth. The estimates presented in Table 4 assume that a hollow-stem auger (HSA) drill rig will be used for installing 2-inch diameter monitoring wells up to 50 feet deep, while a sonic drill rig is assumed for installing 2-inch monitoring wells between 50 and 200 feet deep. HSA is generally the cheapest drilling method for installing shallow monitoring wells (estimated to be $79 per foot of completed well), but the method does not perform as well at depth (therefore a sonic drill rig, which is $98 per foot of completed well, was assumed for the deeper wells). The use of two drill rigs should help minimize costs if numerous wells are installed since the difference in per-foot drilling costs will offset additional mobilization costs; if only a few wells are installed however, it may be more cost effective to use only one drill rig. We assume that wells will be completed flush-to-ground and have one hour of development time.

Depending on the final number of wells the GWMA decides to install, it is possible that air rotary drilling may be a better choice for installing deep wells than sonic. Air rotary drilling is significantly faster in basalt than sonic. Therefore, use of an air rotary rig for some or all of the deeper wells may be beneficial, especially if the GWMA installs more than 9 wells (since Preliminary Drill Sites 9, 14, 18, and 24 have higher likelihoods of encountering basalt). While air rotary drilling is quicker than sonic drilling in basalt and at depth, a trade-off occurs if all deep wells are installed with air rotary since less detailed geologic information is generally obtained with that method compared to sonic (such as identifying fine grained material percentages, thin perching layers, and where the water table is encountered), which can increase the likelihood that wells may erroneously be installed at non-targeted depths. Once the total number of wells that will be installed is determined, air rotary cost estimates can be made and compared to cost estimates for mobilizing two deep well rigs (one sonic and one air-rotary).

## 6.2 WELL SAMPLING COSTS

We assumed that passive samplers are used rather than sampling pumps. Passive samplers have lower upfront costs than pumps and should greatly reduce sampling time, resulting in additional cost savings. However, the passive samplers will require further vetting and quality assurance data that may require some duplication. Also, comparisons of long-term costs between passive samplers and pumps are sensitive to who does the sampling – which is not determined at this time.

The presented cost estimates in Table 4 are for one year of monitoring with six sampling events occurring at each well. Laboratory costs assume that nitrate, nitrite, ammonium, and Total Kjehldahl nitrogen are analyzed in accordance with the Interim Final Groundwater Monitoring Plan (PGG, 2014). However, the separate analyses for nitrate and nitrite will require samples to be analyzed within 48 hours of collection – which will be difficult and expensive to achieve as a result of frequent shipments to the lab and possible lab surcharges for quick analysis. Combined analysis of nitrate-plus-nitrite is a common analysis approach, would reduce cost, and is a recommended change to the Sampling and Analysis Plan for this project[6].

## 6.3 DRAIN SAMPLING COSTS

We assume few costs related to establishment of drain sampling stations are necessary, and include only updating the groundwater sampling and analysis plan and field verifying the sample locations. Sampling costs in Table 5 are for six rounds over one year. Samples would be obtained by filling bottles in the field. Sampling personnel have not been determined, but an estimate for the labor if performed by PGG is included.

# 7.0 NETWORK INSTALLATION PROCESS & SCHEDULE

The table below summarizes a process for further work on the ambient monitoring networks. Possible dates are included for each step assuming that each step is pursued without delay following completion of prior necessary steps. The estimated schedule considers County, Data Committee, and GWAC management processes, but our assessment of the duration of management decision times may be optimistic. In summary, drain sam-

[6] Nitrite is very unlikely to comprise a significant portion of the total nitrogen content in groundwater.

pling should be possible in early 2017, and wells should be able to be installed in the next deep-water-table season (winter-spring 2017).

| Work Common to Wells and Drains | |
|---|---|
| Finalize this report after Data Committee review (August 2016). | |
| Determine who will conduct sampling, surveying, and technical oversight. Then develop cost estimates for ancillary work related to well installation and sampling and analysis of wells and drains (July - September 2016). | |
| Allocate available funds between well installation, well sampling and analysis, and drain sampling and analysis (September – October 2016). | |
| **Work Specific to Well Network** | **Work Specific to Drain Network** |
| Field verify and mark preliminary drill sites. Include evaluation of possible interference from underground utilities (One-Call). Revisit sites after utilities are marked, and move drill sites if necessary to avoid utilities. (October – November 2016). | Determine whether the USGS and RSBJC are collecting drain water quality data that will meet GWMA monitoring needs. (October 2016). |
| Develop drilling specifications. Generate bid package for well drilling. Select drilling contractor. (November 2016 – January 2017). | Field verify and mark drain sampling stations. Move stations to accommodate access if necessary. Obtain access agreements if necessary. (October - November 2016). |
| Obtain any permits necessary for drill site access, including traffic control during field work. (November – December 2016). | Develop a Drain Sampling and Analysis Plan (SAP). This document could be an addendum to the Interim Final Groundwater Monitoring Plan (PGG, 2014a) or its successor. (Submit to Data Committee October – November 2016). |
| Schedule drilling for late winter or spring when water table is deepest. Re-mark drill locations and utilities one week prior to drilling if delay has removed field marks. (January – March 2017). | Contract with samplers and laboratory. (November – December 2016). |
| Drill wells, logging geology and documenting well as-builts and brief well tests. Survey wellhead locations and elevations. (January – March 2017). | Begin sampling drains. Consider initial frequency of 6/year (stage and nitrate concentration) to assess seasonality and possible surface water dilution, followed by lower frequency to capture groundwater-only samples. (January – February 2017). |
| Document well installations (as-built report). (April – May 2017). | |

| | |
|---|---|
| Update the GWMA's Interim Final Groundwater Monitoring Plan (PGG, 2014a) if necessary to implement changes, such as use of passive samplers. (April – June 2017, includes two-month Data Committee approval time). | |
| Begin sampling wells. Consider initial frequency of 6/year to assess seasonality, followed by lower frequency to capture desired data. (July 2017). | |

# 8.0 REFERENCES


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# **APPENDIX A**
# **LOCAL MAPS OF PRELIMINARY DRILL SITES**